

# **Natural Conditions Assessment for Low Dissolved Oxygen and pH, Popes Creek and Tributaries in Westmoreland County, Virginia**



**Submitted by  
Virginia Department of Environmental Quality**

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## Executive Summary

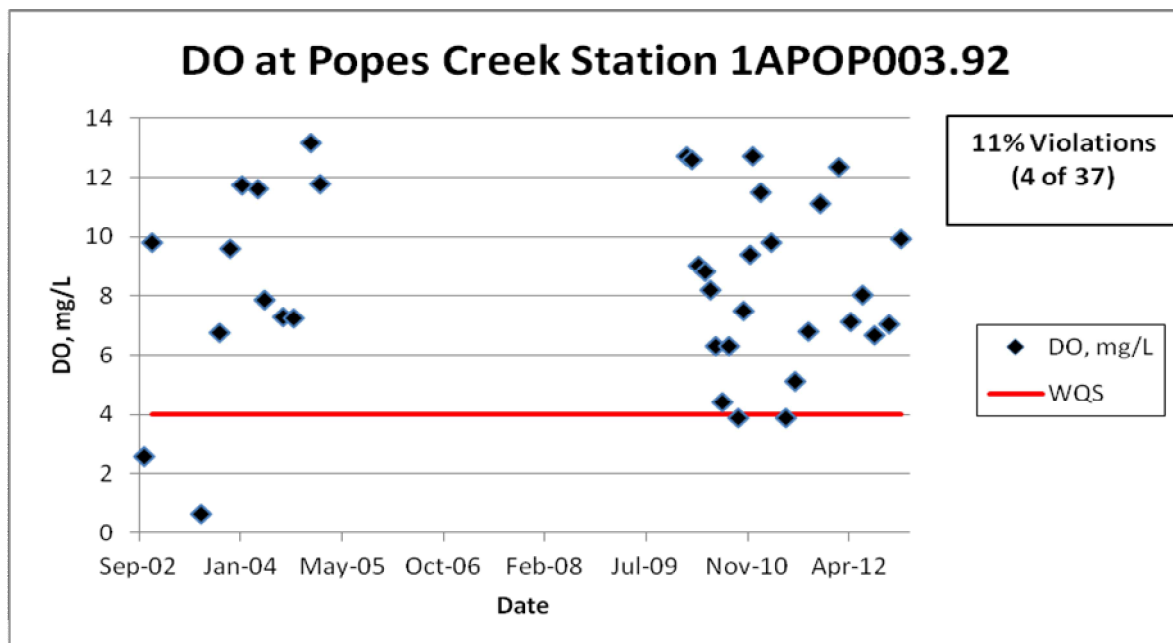
This report presents the assessment of whether low pH and dissolved oxygen (DO) in Popes Creek and tributaries are due to natural conditions or whether a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. Popes Creek is located within Westmoreland County, Virginia, and is a major tributary of Popes Bay, which is a minor tributary of the Potomac River. The waterbody identification (WBID) code for Popes Creek is VAP-A31R. Popes Creek encompasses a total of approximately 46.83 rivermiles (National Hydrography Dataset (NHD)). Popes Creek and tributaries were listed as impaired due to violations in water quality standards for DO and pH. This report addresses both the DO and pH impairments.

The total area of the Popes Creek and tributaries watershed is approximately 17.51 square miles. There is approximately 0.573 sq. mile (367 acres) of tidal estuary in the watershed. The average annual rainfall is 42.53 inches. The watershed is predominately forest (57 percent). Agriculture (hay/pasture 4.7 percent and cropland 13.5 percent) comprises 18 percent of the watershed. Urban areas comprise approximately 4 percent of the land base. Wetlands comprise 9 percent of the watershed. The remaining 11.5 percent of the watershed is comprised of 7.4 percent other grasses and 4.1 percent open water. Land use was not considered to have significantly impacted the swampwater conditions of Popes Creek and tributaries.

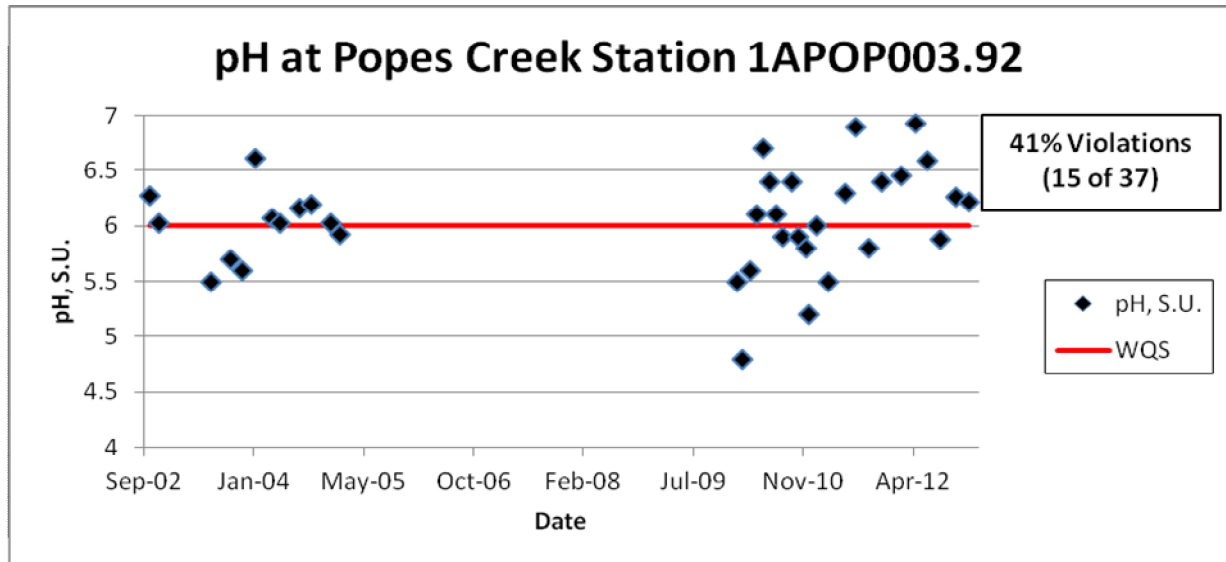
The Popes Creek watershed above the head of tide was listed as impaired on Virginia's 2006, 2008, 2010 and 2012 305(b) / 303(d) Integrated Reports (VADEQ, 2006, 2008, 2010 and 2012) due to violations of the State's water quality standard for DO and pH. The Canal Swamp watershed was added to the impairment in the 2012 305(b)/303(d) Integrated Report (VADEQ 2012).

DEQ monitored 8 stations on Popes Creek and tributaries with dates ranging from April 1996 through December 2012. Of the 114 total pH data points recorded, 58 violated water quality standards for pH (51%), and 11 of 114 DO data points violated the water quality standards for DO concentration (9.6%). The pH minimum and maximum values ranged from 3.6 to 7.5 S.U., and DO values ranged from 0.6 to 13.3 mg/L. All 8 stations violated the pH water quality standards more than 10.5% of samples. Most of the DO violations occurred in three stations, which each violated the DO water quality standards in more than 10.5% of samples. Figures E1 and E2 show DO and pH concentrations at the listing station 1APOP003.92.

**Figure E1. Time series of DO at Popes Creek station 1APOP003.92, omitting 4/23/1996 DO = 8.35 mg/l.**



**Figure E2. Time series of pH at Popes Creek station 1APOP003.92, omitting 4/23/1996 pH = 5.86 S.U.**



According to Virginia Water Quality Standards (9 VAC 25-260-10A), “all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).”

As indicated above, Popes Creek and tributaries must support all designated uses and meet all applicable criteria. If the waterbody violates the instantaneous DO water quality standard of 4.0 mg/l or pH values are less than 6.0 or greater than 9.0 in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

In 2003 VADEQ proposed a methodology for determining whether low DO or pH originates from natural or anthropogenic sources, adapted from “Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia” (MapTech 2003).

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. Conditions that would typically be associated with naturally low DO include slow-moving, ripple-less waters where the bacterial decay of organic matter depletes DO at a faster rate than it can be replenished. Indicators of these conditions include low slope, the presence of swamps or wetlands. These conditions often also produce low pH due to organic acids (tannins, humic and fulvic substances) produced in the decay process. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in free-flowing streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or low pH levels and for determining the likelihood of anthropogenic impacts is described below. DEQ staff use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Before implementing this procedure, all DO and pH data should be screened for flows less than the 7Q10. DO and pH data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly.

- Step 1. Determine slope and appearance (presence of wetlands).
- Step 2. Determine nutrient levels and compare with USGS background concentrations.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts from permitted dischargers and land use.

There was one date with DO and pH data collected at 1APOP003.92, on 9/26/2002, when flows were estimated to be less than 7Q10 from the drainage area comparison with Piscataway Creek. The DO that day was 2.57 mg/L and pH was 6.27 S.U. These two data points were removed from the dataset and percent violations recalculated to be 8.3% violations for DO and 42% violations for pH at the listing station 1APOP003.92. DEQ does not recommend de-listing Popes Creek for low DO based on the reduction in DO percent violations from 10.8 to 8.3 percent at the listing station, because both Fox Hall and Canal Swamps still have 15 and 38 percent DO violations, respectively.

The percent slope of Popes Creek and tributaries ranged from 0.25% to 0.34% slope. These were below the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swampy areas and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

Visual inspection of Popes Creek and tributaries revealed swampy areas and heavy tree canopy in large swamp segments. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs.

The VADEQ collected nutrient data from the original listing station 1APOP003.92 (July 2003 to December 2012). The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations were below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

The VADEQ also collected TN and TP nutrient data from the ambient watershed network station 1ACAS000.58 on Canal Swamp, a tributary of tidal Popes Creek (Feb 2009 to Nov 2010). The TN of 1.147 mg/l was 15 percent above the USGS (1999) background TN value of 1.0 mg/l. The average TP of 0.113 mg/l was 13 percent above the USGS (1999) background TP value of 0.1 mg/l. There are no permitted dischargers in the Canal Swamp and tributaries watershed. There is a small amount of agricultural land use in the Canal Swamp watershed, most of which is located along Rt. 624, east of Canal Swamp. Canal Swamp rises in the Westmoreland State Park where there is mostly forested land. The urban land use exists sparsely only along the roadways, totaling approximately 42 homes, and in Westmoreland State Park 12 cabins and some tent camping sites with one or two bathrooms. However, only approximately 3 of the homes are within one mile upstream of the station. Also on one sample date, September 27, 2010, abnormally high TN of 2.9 mg/L and TP of 0.43 mg/L were sampled. This almost always occurs during very high storm runoff, however flow was noted to be low on this date. While these concentrations were elevated, the low flow means that the nutrient load to the watershed on this date was also low. There appears to be slight anthropogenic impact upon the sampling station, therefore this TN and TP in Canal Swamp were considered to be of primarily natural origin and not sufficient reason to preclude natural Class VII designation, especially given the low nutrient levels in the Popes Creek watershed upstream of the original listing station.

Popes Creek and tributaries exhibit natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Popes Creek and tributaries watershed.

The watershed is approximately 11206 acres (17.51 mi<sup>2</sup>) in size and is predominately forest (57 percent). Agriculture (hay/pasture 4.7 percent and cropland 13.5 percent) comprises 18 percent of the watershed.

Urban areas comprise approximately 4 percent of the land base. Wetlands comprise 9 percent of the watershed. The remaining 11.5 percent of the watershed is comprised of 7.4 percent other grasses and 4.1 percent open water. Per most recent aerial photography there are 128 homes in the Popes Creek watershed and 42 homes in the Canal Swamp watershed. This equates to approximately home structure per 66 acres. However only 19 homes are within one mile upstream of the two sampling stations and 161 are farther than one mile away and approximately half of those are on Rt. 640 the greatest distance from the Popes Creek sampling station. Land use was not considered to have significantly impacted the swampwater conditions of Popes Creek and tributaries.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for Popes Creek and tributaries located in waterbody identification codes (WBID) VAP-A31R. This obviates the need for a future DO and pH TMDL for the watershed.

DEQ performed the assessment of the Popes Creek and tributaries low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

## **1. Introduction**

Popes Creek and tributaries are located within Westmoreland County, Virginia, and are minor tributaries of the Potomac River. There are 46.83 total stream miles in the Popes Creek watershed (National Hydrography Dataset (NHD)) using GIS. Popes Creek is fed by eleven named tributaries: Canal Swamp, Potter Branch, Thomas Branch, Morris Run, Flamstead Hill Swamp, Tates Swamp, Ware Branch, Bundys Swamp, Walnut Hill Run, Fox Hall Swamp, Gravel Run and one unnamed tributary (UT) to Bundys Swamp. The impaired segment for low dissolved oxygen (DO) and pH in Popes Creek and tributaries totals 36.61 miles. Popes Creek and tributaries generally flow northeast from their headwaters 2 miles south of Oak Grove, VA, to the Potomac River.

## **2. Physical Settings**

### **2.1. Listed Water Bodies**

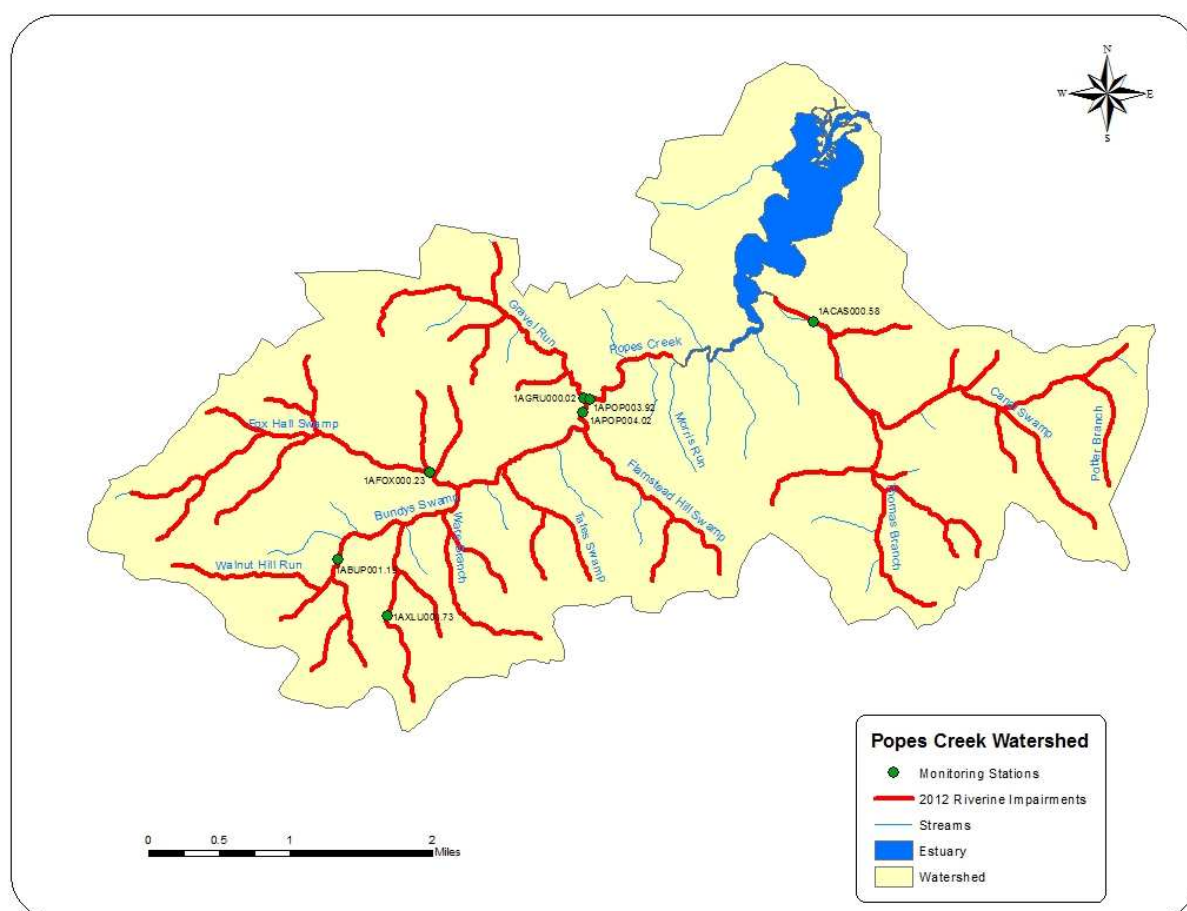
The Popes Creek watershed above the head of tide was listed as impaired on Virginia's 2006, 2008, 2010 and 2012 305(b) / 303(d) Integrated Reports (VADEQ, 2006, 2008, 2010 and 2012) due to violations of the State's water quality standard for DO and pH. The Canal Swamp watershed was added to the impairment in the 2012 305(b)/303(d) Integrated Report (VADEQ 2012). This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL. The waterbody identification code (WBID, Virginia Hydrologic Unit) for non-tidal Popes Creek is VAP-A31R.

### **2.2. Watershed**

#### **2.2.1. General Description**

Popes Creek and tributaries generally flow northeast from the headwaters 2 miles south of Oak Grove, VA, to the Potomac River. The watershed totals approximately 17.51 mi<sup>2</sup>. There is no continuous flow gaging station on Popes Creek and tributaries. See Figure 1 for a map of the watershed including 7 monitoring stations. There is approximately 0.573 sq. mile (367 acres) of tidal estuary in the watershed.

**Figure 1. The Popes Creek watershed map and associated monitoring stations.**



## 2.2.2. Geology, Climate, Land Use

### **Geology and Soils**

The impaired segment of Popes Creek and tributaries is within the Atlantic Coastal Plain physiographic region. The Atlantic Coastal Plain is the easternmost of Virginia's physiographic provinces. The Atlantic Coastal Plain extends from New Jersey to Florida, and includes all of Virginia east of the Fall Line. The Fall Line is the easternmost extent of rocky river rapids, the point at which east-flowing rivers cross from the hard, igneous and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the Coastal Plain. The Coastal Plain is underlain by layers of Cretaceous and younger clay, sand, and gravel that dip gently eastward. These layers were deposited by rivers carrying sediment from the eroding Appalachian Mountains to the west. As the sea level rose and fell, fossiliferous marine deposits were interlayered with fluvial, estuarine, and beach strata. The youngest deposits of the Coastal Plain are sand, silt and mud presently being deposited in our bays and along our beaches ([http://www.dcr.virginia.gov/natural\\_heritage/documents/overviewPhysiography\\_vegetation.pdf](http://www.dcr.virginia.gov/natural_heritage/documents/overviewPhysiography_vegetation.pdf)).

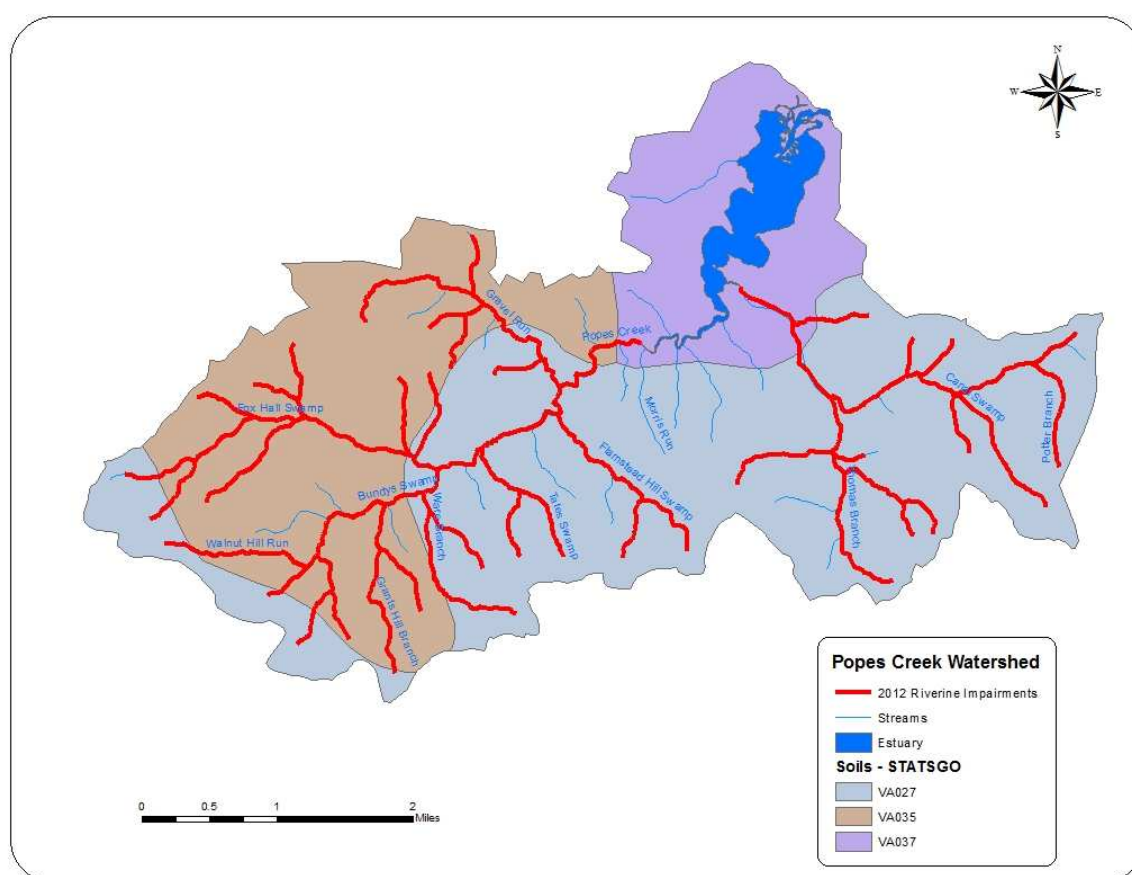
Soils for the Popes Creek and tributaries watershed were documented utilizing the VA State Soil Geographic Database (STATSGO). Three general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (<http://soils.usda.gov/technical/classification/osd/index.html>). Figure 2 shows the location of these general soil types in the watershed.

Soils of the Emporia-Johnston-Kenansville-Remlik-Rumford-Slagle-Suffolk-Tomotley (VA027) series are very deep to deep, and vary between well drained to poorly drained with moderately slow or slow permeability. They formed in moderately fine-textured stratified fluvial and marine sediments on the upper Coastal Plain and stream terraces.

The soils of the Craven-Mattaponi-Lenoir-Coxville (VA035) series are very deep in which the drainage ranges from somewhat poor to well drained and the permeability is typically slow to moderately slow. The soils formed in flats or depressions from the lower to upper Coastal Plain and Piedmont Physiographic Provinces of the Atlantic Coast, in which the parent materials consists of fluvial and marine sediments.

The Portsmouth - Roanoke - Rains - Eunola - Levy - Kalmia Series (VA037) are very deep, very poorly to moderately well drained soils. These soils are located on low stream or marine terraces and in marshes of the Atlantic Coastal Plain. These series are formed from fluvial and marine sediments. Permeability of these soil types ranges from very slow to rapid, depending on soil composition.

**Figure 2. Soil Characteristics of the Popes Creek and tributaries Watershed.**



### ***Climate***

The climate summary for Popes Creek and tributaries comes from a weather station located in Warsaw, VA (448894) with a period of record from 1893 to 2012. The average annual maximum and minimum temperatures (°F) at the weather station are 68.3 and 46.6 and the annual rainfall (inches) is 42.53 (Table 1) (Southeast Regional Climate Center, [http://www.sercc.com/climateinfo/historical/historical\\_va.html](http://www.sercc.com/climateinfo/historical/historical_va.html)). SERCC also maintained a weather station at Colonial Beach, VA much closer to Popes Creek, but the period of record was only from 1963 to 2002, with average annual maximum and minimum temperatures (°F) at the station of 69.6 and 47.4 and the annual rainfall (inches) of 41.18.

**Table 1. Climate summary for Warsaw, Virginia (448894).**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
<b>Average Max. Temperature (F)</b>	47.2	49.1	58.4	68.7	77.4	84.7	88.0	86.6	80.7	70.6	59.8	49.3	68.3
<b>Average Min. Temperature (F)</b>	27.4	28.4	35.6	44.3	53.8	62.6	66.7	65.7	59.1	47.7	38.4	30.1	46.6
<b>Average Total Precipitation (in.)</b>	3.10	2.81	3.73	3.11	3.76	3.82	4.44	4.58	3.77	3.27	3.00	3.14	42.53

### **Land Use**

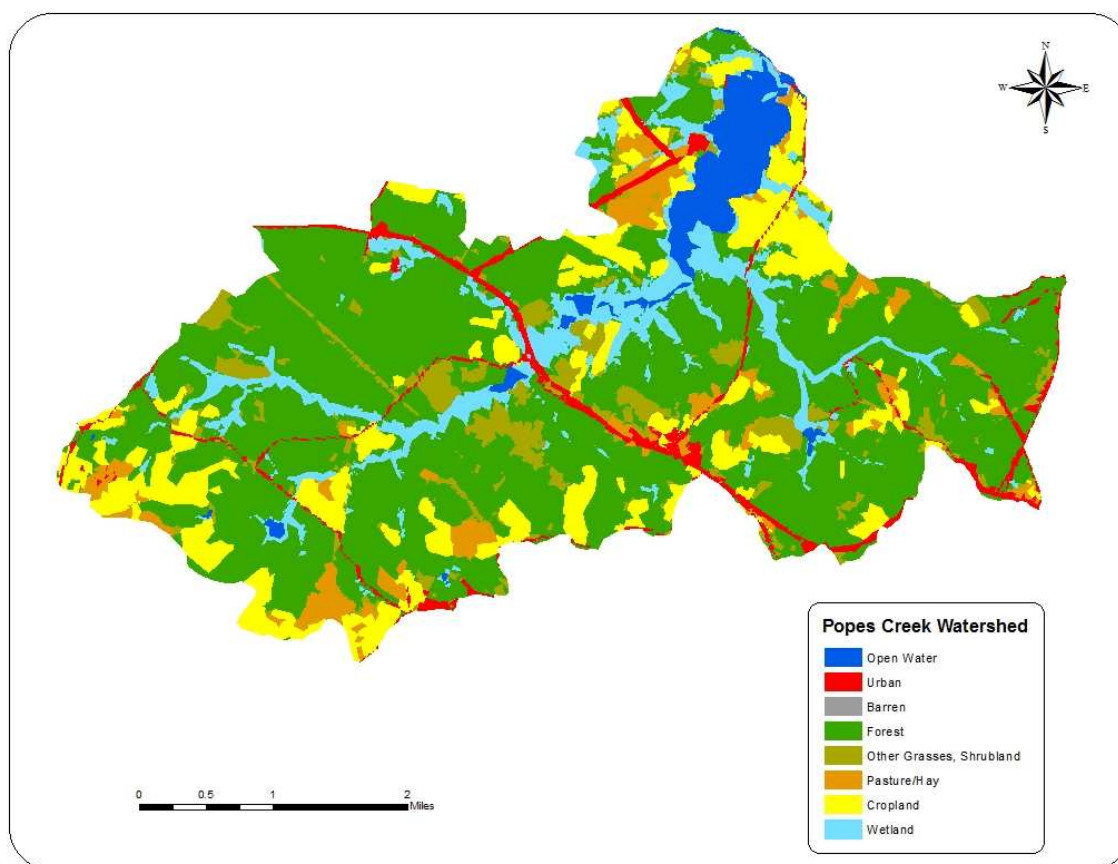
The Popes Creek and tributaries watershed extends from approximately two miles south of Locust Grove, VA, eastward to Baynesville, VA, to the Potomac River. It is approximately 3 miles long and 5 miles wide. The watershed is approximately 11206 acres (17.51 mi<sup>2</sup>) in size and is predominately forest (57 percent). Agriculture (hay/pasture 4.7 percent and cropland 13.5 percent) comprises 18 percent of the watershed. Urban areas compose approximately 4 percent of the land base. Wetlands comprise 9 percent of the watershed. The remaining 11.5 percent of the watershed is comprised of 7.4 percent other grasses and 4.1 percent open water. Land use acres and percentages were affected by rounding. Land use is described in Table 2.

A map of the distribution of land use in the watershed (Figure 3) shows that urban land use is concentrated along US. Rt. 3 and county roads with a small concentration at Morris Store and Flat Iron. Wetlands are concentrated in a swath east to west along the mainstems of Popes Creek and Canal Swamp.

**Table 2. Land Use in the Popes Creek and Tributaries Watershed**

<b>Land Use Type</b>	<b>Acres</b>	<b>Square Miles</b>	<b>Percent</b>
Open Water	455	0.71	4.1%
Urban	455	0.71	4.1%
Barren	0	0	0.0%
Forest	6420	10.03	57.3%
Pasture/Hay	519	0.81	4.7%
Cropland	1511	2.36	13.5%
Other Grasses	832	1.30	7.4%
Wetland	1011	1.58	9.0%
<b>Totals:</b>	<b>11206</b>	<b>17.51</b>	<b>100%</b>
<b>Land Use Type</b>	<b>Acres</b>	<b>Square Miles</b>	<b>Percent</b>

**Figure 3. Land Use in the Popes Creek and tributaries Watershed**



### 3. Description of Water Quality Problem/Impairment

The Popes Creek watershed above the head of tide was listed as impaired on Virginia's 2006, 2008, 2010 and 2012 305(b) / 303(d) Integrated Reports (VADEQ, 2006, 2008, 2010 and 2012) due to violations of the State's water quality standard for DO and pH. The Canal Swamp watershed was added to the impairment in the 2012 305(b)/303(d) Integrated Report (VADEQ 2012). This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL. There is a tidal segment totaling approximately 31 acres between the mainstem head of tide on Popes Creek and a nontidal tributary named Canal Swamp entering from the right bank, which was included in the low DO / pH impairment.

DEQ monitored 8 stations on Popes Creek and tributaries (see Figure 1) with dates ranging from April 1996 through December 2012. Of the 114 total pH data points recorded, 58 violated water quality standards for pH (51%), and 11 of 114 DO data points violated the water quality standards for DO concentration (9.6%). The pH minimum and maximum values ranged from 3.6 to 7.5 S.U., and DO values ranged from 0.6 to 13.3 mg/L. All 8 stations violated the pH water quality standards more than 10.5% of samples. Most of the DO violations occurred in three stations, which each violated the DO water quality standards in more than 10.5% of samples. The results are summarized in Table 3.

**Table 3. pH and DO data collected by DEQ from 8 stations on Popes Creek and tributaries.**

Station	Sample Period	Number of Samples		SU		mg/l		Number of Violations	
		pH	DO	Average pH	Min-Max pH	Average DO	Min-Max DO	pH	DO
1APOP003.92	4/23/1996 to 12/12/2012	37	37	6.04	4.8 – 6.93	8.37	0.65 – 13.17	15	4
1ACAS000.58	4/23/1996 to 11/4/2010	13	13	6.2	5.2 – 7.5	6.76	0.6 – 12.3	4	5
1AGRU000.02	4/23/1996 to 12/15/2010	13	13	5.19	3.6 – 6.5	8.39	5.3- – 12.7	12	0
1APOP004.02	1/19/2010 to 12/15/2010	12	12	6.12	4.8 – 7.1	9.04	5.6 – 13.3	3	0
1AFOX000.23	4/23/1996 to 12/15/2010	13	13	5.40	4.1 – 6.1	6.4	1.8 – 12.4	12	2
1AFOX002.12	4/23/1996	1	1	5.73	5.73	8.37	8.37	1	0
1ABUP001.19	4/23/1996 to 12/15/2010	13	13	5.89	4.8 – 7.1	7.72	5.3 – 11.7	7	0
1AXLU000.73	1/9/2010 to 2/22/2011	12	12	6.04	5.0 – 6.9	9.95	5.8 – 13.2	4	0

Time series graphs of all DO and pH data collected at the original listing station, Popes Creek at station 1APOP003.92 shows the DO ranged from 0.65 to 13.17 mg/L and the pH ranging from 4.8 to 6.93 S.U. (Figure 4 and Figure 5) respectively. The horizontal red line at the DO = 4.0 mark represents the minimum water quality standard in Figure 4. The data points below the DO = 4.0 line are violations of the water quality standard in Figure 4. The horizontal red line at the pH = 6.0 mark represents the minimum water quality standard in Figure 5. The data points below the pH = 6.0 line are violations of the water quality standard in Figure 5.

Figure 4. Time series of DO at Popes Creek station 1APOP003.92, omitting 4/23/1996 DO = 8.35 mg/l.

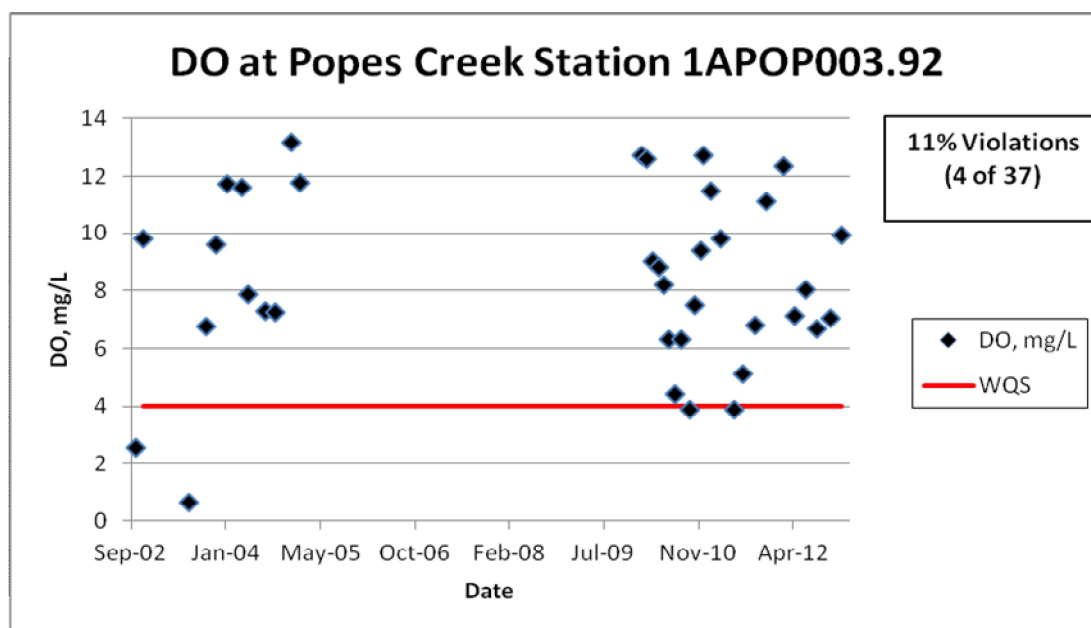
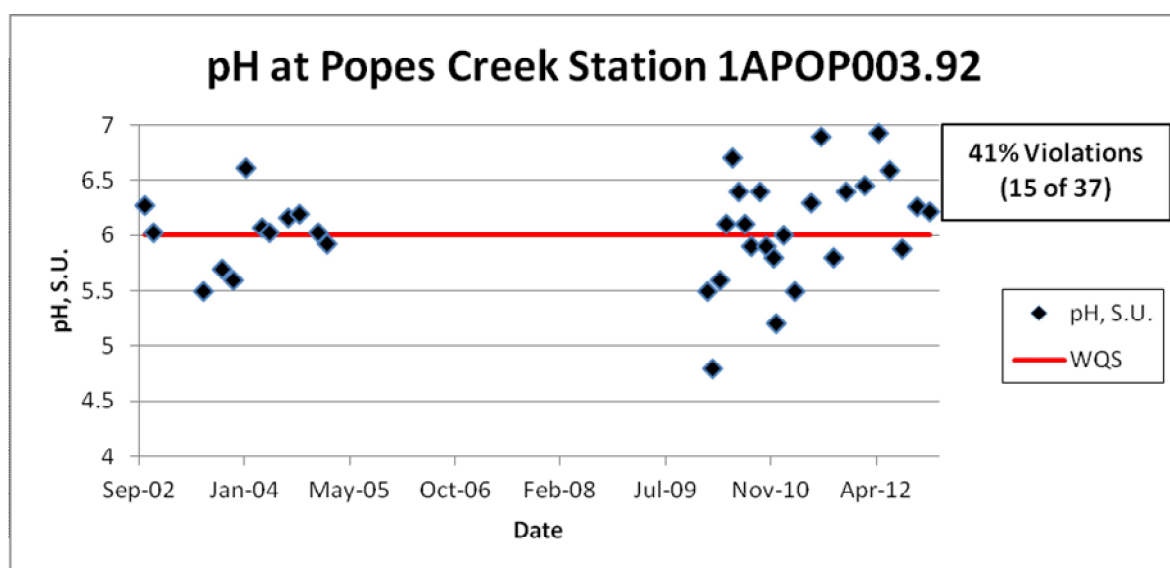


Figure 5. Time series of pH at Popes Creek station 1APOP003.92, omitting 4/23/1996 pH = 5.86 S.U.

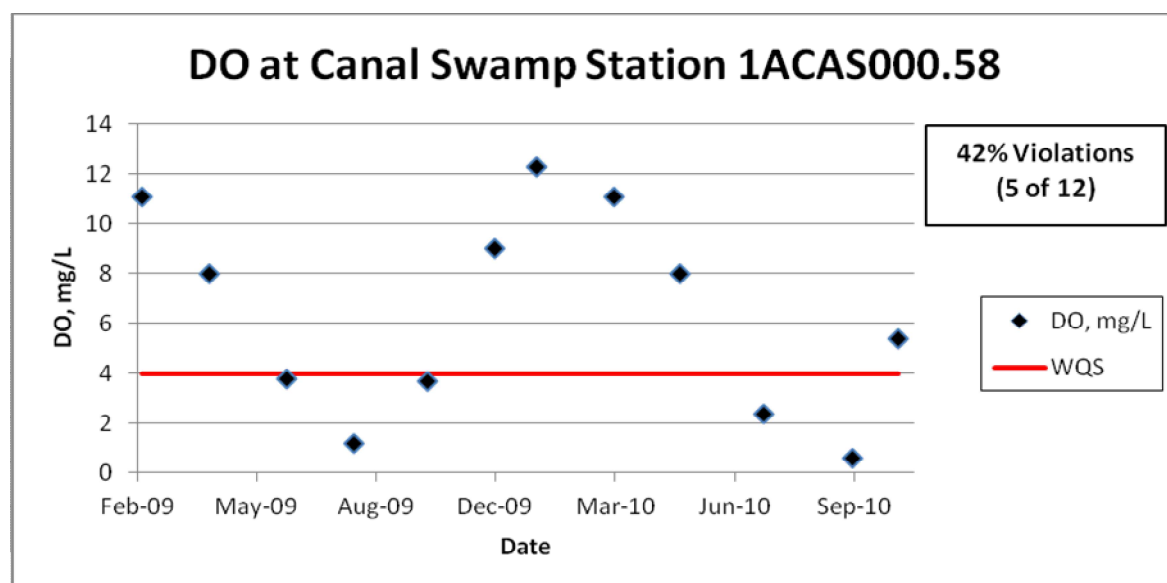


### 3.1. Associated pH and DO of Popes Creek and Tributaries

DEQ also monitored DO and pH data at seven other stations on Popes Creek and tributaries for the assessment of low DO and pH due to the natural conditions. All 7 associated stations violated the pH water quality standards more than 10.5% of samples. Two associated stations violated the DO water quality standards more than 10.5% of samples. Four stations (1AGRV000.02, 1APOP004.02, 1ABUP001.19 and 1AXLU000.73) did not violate the DO water quality standard and were not charted below. One station

(1AFOX002.12) had only one station visit and was also not charted below. See Figures 6 through 13 for time series of DO and pH at associated Popes Creek and tributary stations.

**Figure 6. Time series of DO at Canal Swamp, 1ACAS000.58, omitting 4/23/1996 DO = 11.26 mg/l.**



**Figure 7. Time series of pH at Canal Swamp, 1ACAS000.58, omitting 4/23/1996 pH = 5.20 S.U.**

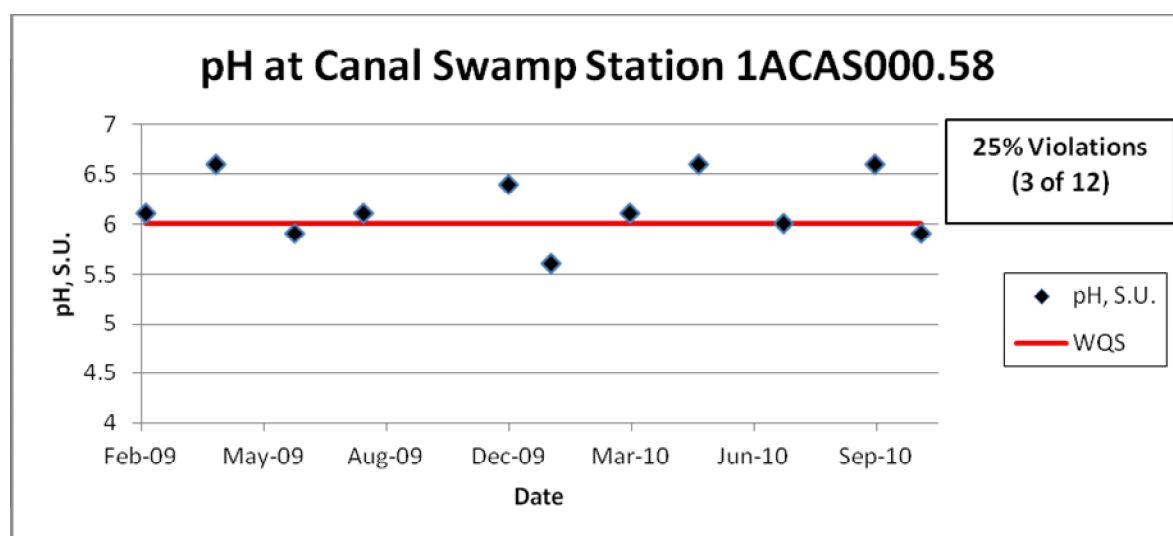


Figure 8. Time series of pH at Gravel Run, 1AGRV000.02, omitting 4/23/1996 pH = 5.89 S.U. DO was not charted because there were no DO violations.

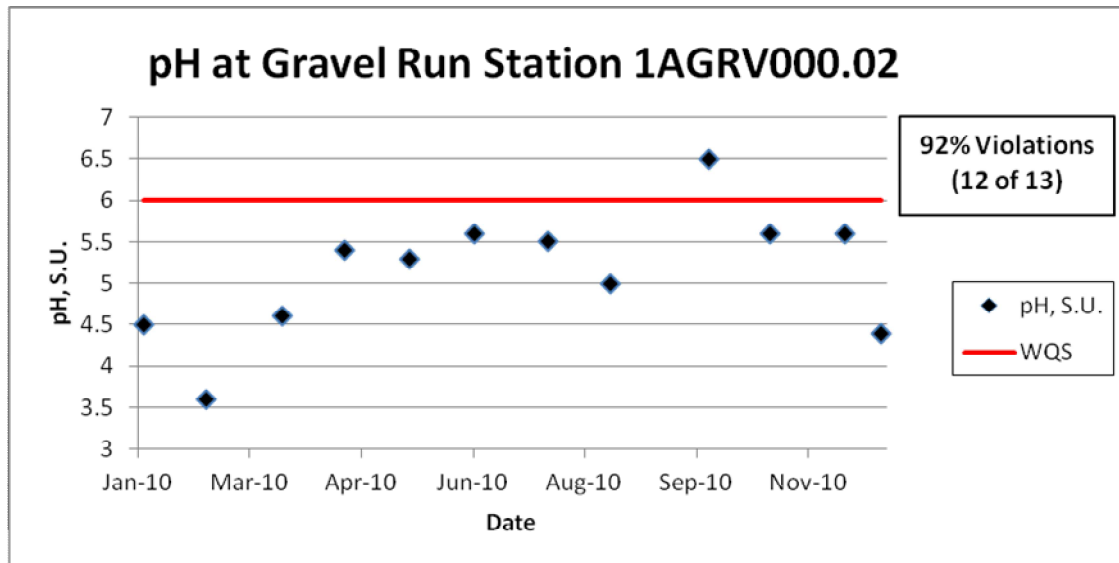


Figure 9. Time series of pH at Popes Creek, 1APOP004.02. DO was not charted because there were no DO violations.

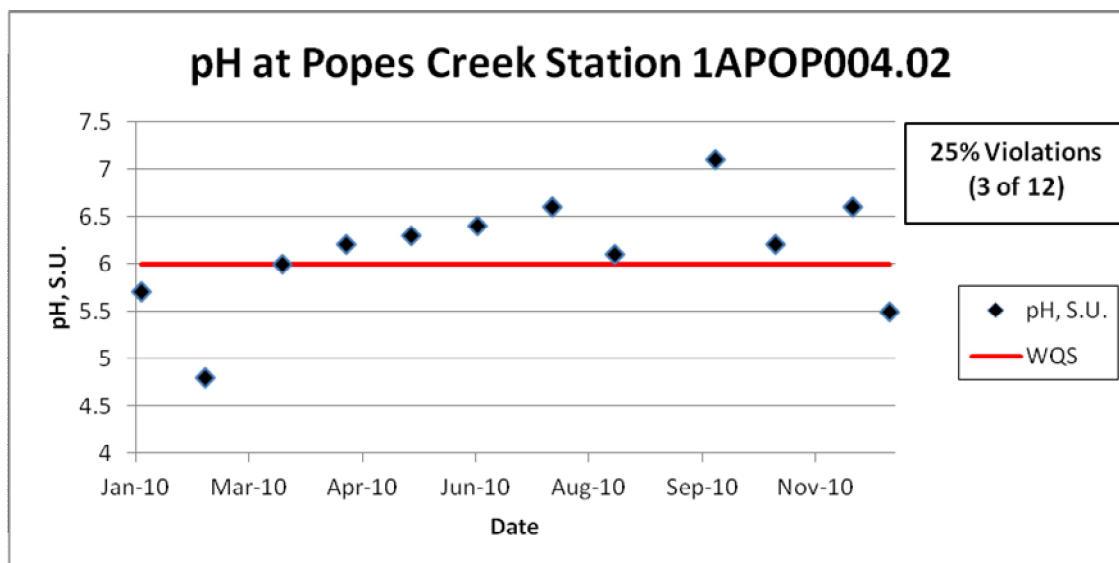


Figure 10. Time series of DO at Fox Hall Swamp, 1AFOX000.23, omitting 4/23/1996 DO = 4.4 mg/l.

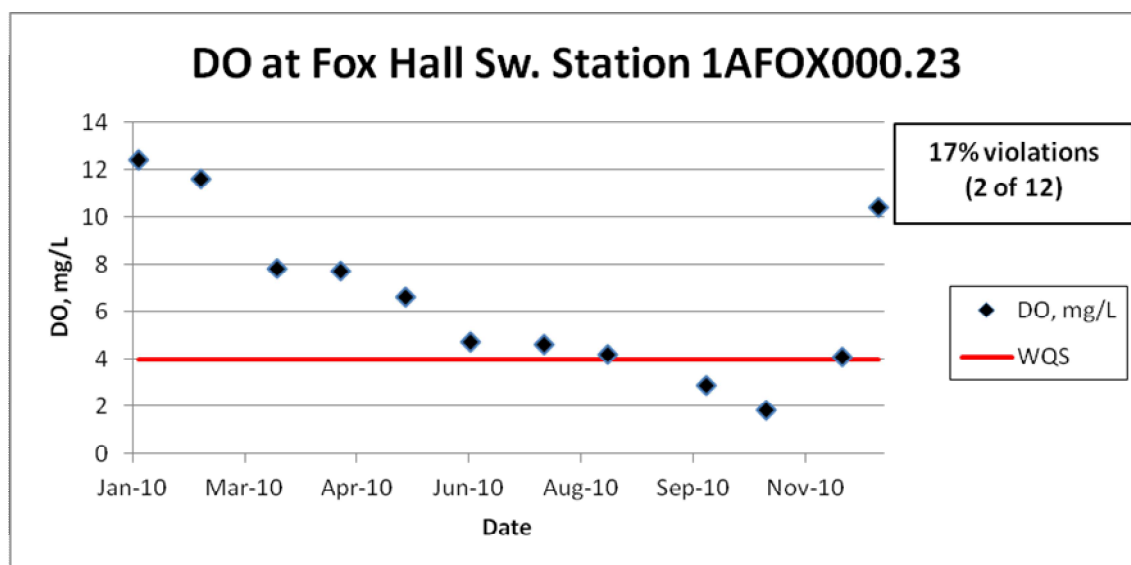
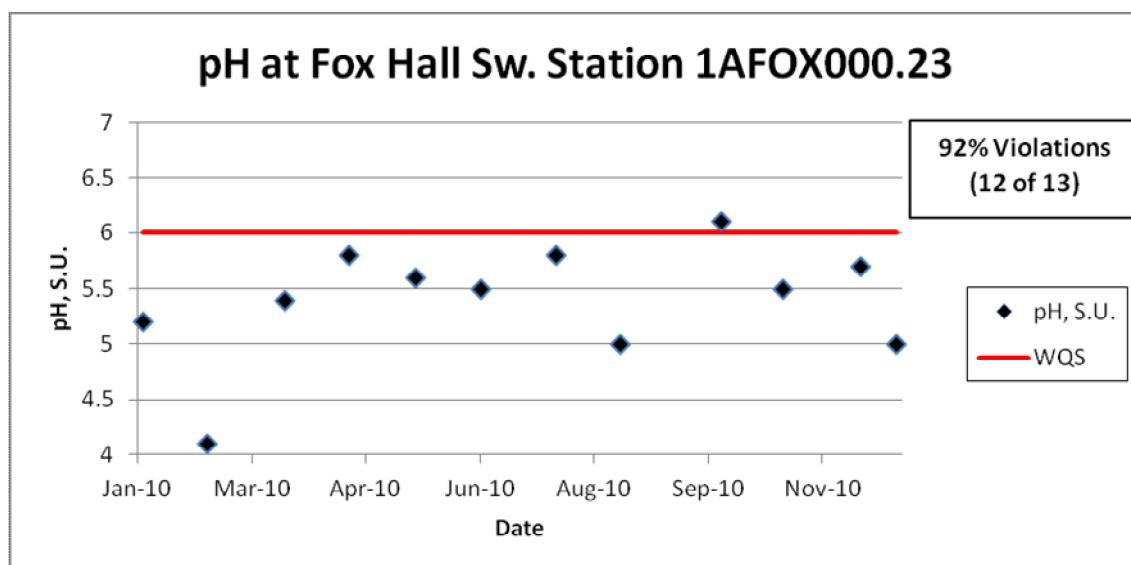
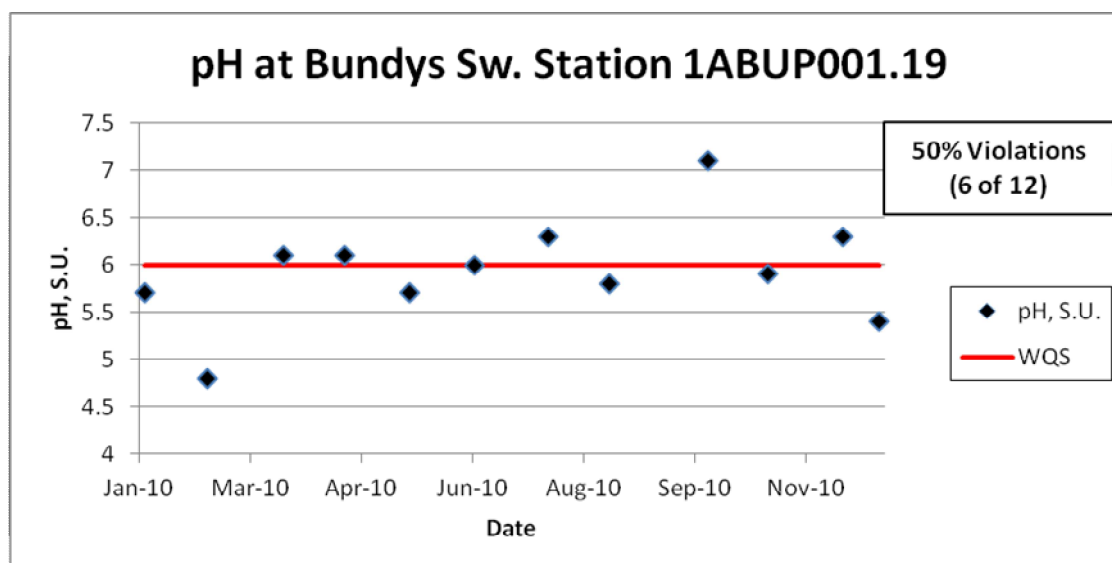


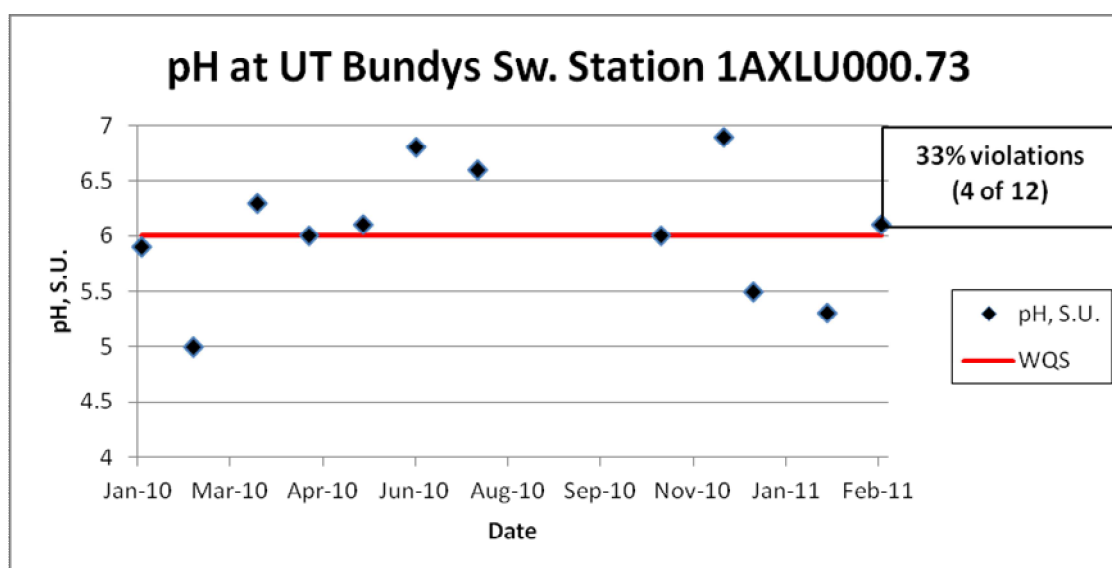
Figure 11. Time series of pH at Fox Hall Swamp, 1AFOX000.23, omitting 4/23/1996 pH = 5.5 S.U.



**Figure 12. Time series of pH at Bundys Swamp, 1ABUP001.19, omitting 4/23/1996 pH = 5.33 S.U. DO was not charted because there were no DO violations.**



**Figure 13. Time series of pH at UT to Bundys Swamp, 1AXLU000.73. DO was not charted because there were no DO violations.**



## 4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term “water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.).”

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

#### 4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), “all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).”

As stated above, Popes Creek must support all designated uses and meet all applicable criteria.

#### 4.2. Applicable Water Quality Criteria

The applicable water quality criteria for DO and pH in the Popes Creek watershed are an instantaneous minimum DO of 4.0 mg/l and pH from 6.0 SU to 9.0 SU, as in Table 4.

Table 4. Applicable water quality standards		
Parameter	Minimum, mg/l	Maximum, mg/l
pH	6.0	9.0
DO	4.0	-

If the waterbody exceeds the criterion listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

### 5. Assessment of Natural Conditions Affecting low DO - Process for determining if DO and pH impairments in free-flowing streams are due to natural conditions.

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity. Conditions in a stream that would typically be associated with naturally low DO and pH include slow-moving, ripple-less waters or wetlands where the decay of organic matter produces organic acids. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below.

- Step 1. Determine slope and appearance.
- Step 2. Determine nutrient levels.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts.

**The results from this methodology (or process or approach) will be used to determine if the stream should be re-classified as Class VII Swamp Waters. Each step is described in detail below.**

# Procedure for Natural Condition Assessment of low pH and low DO in Virginia Streams

Prepared by Virginia Department of Environmental Quality  
October 2004

## I. INTRODUCTION

Virginia's list of impaired waters currently shows many waters not supporting the aquatic life use due to exceedances of pH and/or DO criteria that are designed to protect aquatic life in Class III waters. However, there is reason to believe that most of these streams or stream segments have been mis-classified and should more appropriately be classified as Class VII, Swamp Waters. This document presents a procedure for assessing if natural conditions are the cause of the low pH and/or low DO levels in a given stream or stream segment.

The level of dissolved oxygen (DO) in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of acidity as registered by pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity.

Conditions in a stream that would typically be associated with naturally low DO and/or naturally low pH include slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids (tannins, humic and fulvic substances). These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Waters that are shown to have naturally low DO and pH levels will be re-classified as Class VII, Swamp Waters, with the associated pH criterion of 4.3 to 9.0 SU. An associated DO criterion is currently being developed from swamp water data. A TMDL is not needed for these waters. An assessment category of 4C will be assigned until the waterbody has been re-classified.

## II. NATURAL CONDITION ASSESSMENT

Following a description of the watershed (including geology, soils, climate, and land use), a description of the DO and/or pH water quality problem (including a data summary, time series and monthly data distributions), and a description of the water quality criteria that were the basis for the impairment determination, the available information should be evaluated in four steps.

Step 1. Determine appearance and flow/slope.

Streams or stream segments that have naturally low DO (< 4 mg/L) and low pH (< 6 SU) are characterized by very low slopes and low velocity flows (flat water with low reaeration rates). Decaying vegetation in such swampy waters provides large inputs of plant material that consumes oxygen as it decays. The decaying vegetation in swamp water also produces acids and decreases pH. Plant materials contain polyphenols such as tannin and lignin. Polyphenols and partially degraded polyphenols build up in the form of tannic acids, humic acids, and fulvic acids that are highly colored. The trees of swamps have higher polyphenolic content than the soft-stemmed vegetation of marshes. Swamp streams (blackwater) are therefore more highly colored and more acidic than marsh streams.

Appearance and flow velocity (or slope if flow velocity is not available) must be identified for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. This can be done through maps, photos, field measurements or other appropriate means.

Step 2. Determine nutrient levels.

Excessive nutrients can cause a decrease in DO in relatively slow moving systems, where aeration is low. High nutrient levels are an indication of anthropogenic inputs of nitrogen, phosphorus, and possibly organic matter. Nutrient input can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels.

USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L.

Nutrient levels must be documented for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. Streams with average concentrations of nutrients greater than the national background concentrations should be further evaluated for potential impacts from anthropogenic sources.

Step 3. Determine degree of seasonal fluctuation (for DO only).

Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. Seasonal analyses should be conducted for each potential Class VII stream or stream segment to verify that DO is depressed in the summer months and recovers during the winter, as would be expected in natural systems. A weak seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

Step 4. Determine anthropogenic impacts.

Every effort should be made to identify human impacts that could exacerbate the naturally low DO and/or pH. For example, point sources should be identified and DMR data analyzed to determine if there is any impact on the stream DO or pH concentrations. Land use analysis can also be a valuable tool for identifying potential human impacts.

Lastly, a discussion of acid rain impacts should be included for low pH waters. The format of this discussion can be based either on the process used for the recent Class VII classification of several streams in the Blackwater watershed of the Chowan Basin (letter from DEQ to EPA, 14 October 2003). An alternative is a prototype regional stream comparison developed for Fourmile Creek, White Oak Swamp, Matadequin Creek and Mechumps Creek (all east of the fall line). The example analysis under IV in this document, or the example report prepared for Fourmile Creek, illustrate this approach. For streams west of the fall line, a regional stream comparison for 2004 analyses encompasses Winticomack, Winterpock, and Chickahominy Rivers.

7Q10 Data Screen

If the data warrant it, a data screen should be performed to ensure that the impairment was identified based on valid data. All DO or pH data that violate water quality standards should be screened for flows less than the 7Q10. Data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly. Only those waters with violation rates determined days with flows > or = 7Q10 flows should be classified as impaired.

In some cases, data were collected when flow was 0 cfs. If the 7Q10 is identified as 0 cfs as well, all data collected under 0 cfs flow would need to be considered in the water quality assessment. In those cases, the impairment should be classified as 4C, impaired due to natural conditions, no TMDL needed. However, a reclassification to Class VII may not always be appropriate.

### III. NATURAL CONDITION CONCLUSION MATRIX

The following decision process should be applied for determining whether low pH and/or low DO values are due to natural conditions and justify a reclassification of a stream or stream segment as Class VII, Swamp Water.

If velocity is low or if slope is low (<0.50%) AND  
If wetlands are present along stream reach AND  
If no point sources or only point sources with minimal impact on DO and pH AND  
If nutrients are < typical background  
❖ average (= assessment period mean) nitrate less than 0.6 mg/L  
❖ average total nitrogen (TN) less than 1.0 mg/L, and  
❖ average total phosphorus (TP) are less than 0.1 mg/L AND  
For DO: If seasonal fluctuation is normal AND  
For pH: If nearby streams without wetlands meet pH criteria OR if no correlation between in-stream pH and rain pH,  
  
THEN determine as impaired due to natural condition  
→ assess as category 4C in next assessment  
→ initiate WQS reclassification to Class VII Swamp Water  
→ get credit under consent decree

The analysis must state the extent of the natural condition based on the criteria outlined above. A map showing land use, point sources, water quality stations and, if necessary, the delineated segment to be classified as swamp water should be included.

In cases where not all of these criteria apply, a case by case argument must be made based on the specific conditions in the watershed.

#### 5.1 Preliminary Data Screen for Low Flow 7Q10

The 7Q10 flow of a stream is the lowest streamflow for seven consecutive days that occurs on average once every ten years. The first step for low flow 7Q10 screening is to determine the most accurate 7Q10 available. The 7Q10 flow for Popes Creek may be estimated by a drainage area ratio of the Popes Creek watershed (17.51 mi<sup>2</sup>) with the 7Q10 flow at the long-term continuous gaging station Piscataway Creek near Tappahannock, VA, (USGS:01669000), with a drainage area of 28.0 mi<sup>2</sup> and a 7Q10 of 0.50 cfs (2005). Thus the 7Q10 of Popes Creek is estimated at 0.31 cfs.

The DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow, but **NOT** below 7Q10 flow (9 VAC 25-260-50 \*\*\*). Therefore in streams where the 7Q10 > 0.0 cfs, DO less than 4.0 mg/l taken at flows below 7Q10 are not water quality standard violations. However, in streams where the 7Q10 = 0.0 cfs, **ALL** DO data < 4.0 mg/l are standard violations, even if the flow = 0 cfs when the DO was taken.

There was one date with DO and pH data collected at 1APOP003.92, on 9/26/2002, when flows were estimated to be less than 7Q10 from the drainage area comparison with Piscataway Creek. The DO that day

was 2.57 mg/L and pH was 6.27 S.U. These two data points were removed from the dataset and percent violations recalculated to be 8.3% violations for DO and 42% violations for pH at the listing station 1APOP003.92. DEQ does not recommend de-listing Popes Creek for low DO based on the reduction in DO percent violations from 10.8 to 8.3 percent, because both Fox Hall and Canal Swamps still have 15 and 38 percent DO violations, respectively.

## 5.2 Low slope, Swamps, Wetlands or Large Forested Areas

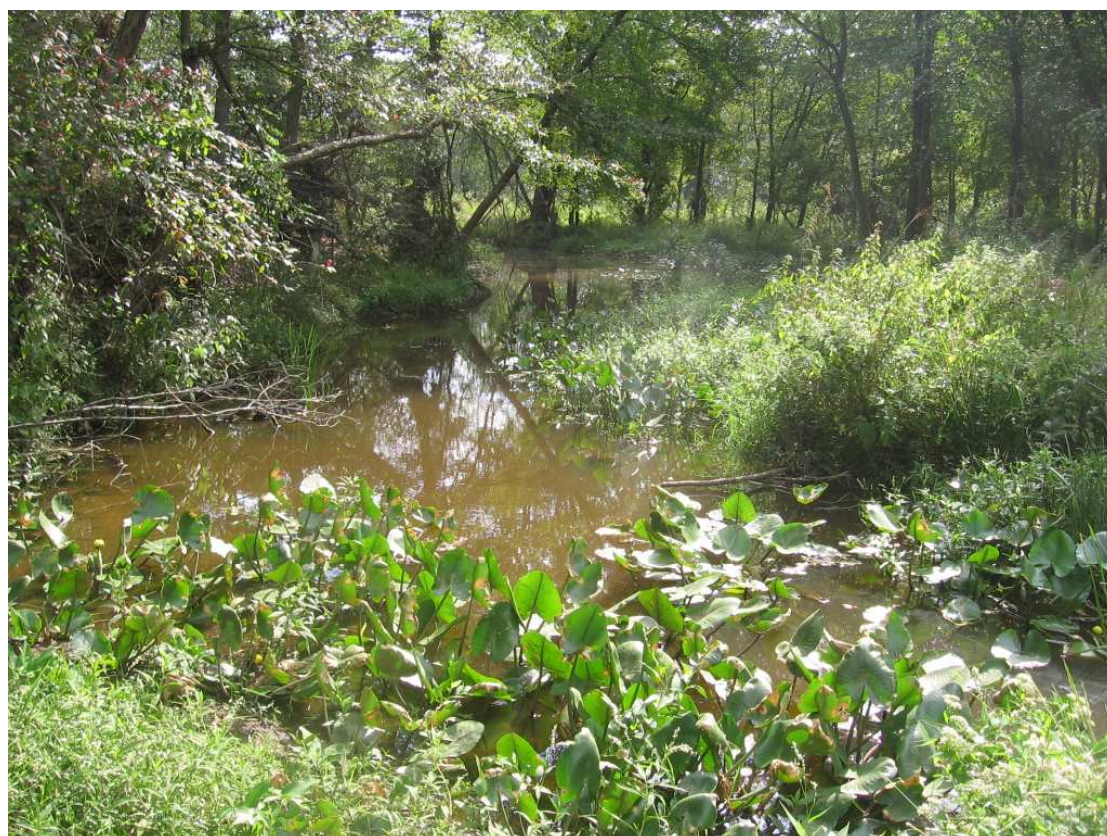
The percent slope of Popes Creek and tributaries ranged from 0.25% to 0.34% slope (Table 5). These were below the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swampy areas and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

**Table 5. Calculated percent slopes for Popes Creek and tributaries.**

Stream	% Slope	Upstream Elevation (Feet) at Rivermile (RM)	Downstream Elevation (Feet) at Rivermile (RM)
Popes Creek + Fox Hall Sw.	0.25	50' at RM 5.25 POP + 1.58 FOX	5' at RM 3.46 POP
Bundys Swamp	0.29	50' at RM 1.38	30' at RM 0.08
Canal Swamp	0.34	50' at RM 2.77	5' at RM 0.23

Visual inspection of Popes Creek and tributaries revealed swampy areas and heavy tree canopy in large swamp segments. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs. (Figures 14 and 15).

**Figure 14. Popes Creek, 150 m downstream of Rt. 3.**



**Figure 15. Fox Hall Swamp at Rt. 639, Upstream.**



### **5.3 Instream Nutrients**

The VADEQ collected nutrient data from the original listing station 1APOP003.92 (July 2003 to December 2012, Table 6). The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

The VADEQ collected nutrient data from the ambient watershed network station 1ACAS000.58 on Canal Swamp, a tributary of tidal Popes Creek (Feb 2009 to Nov 2010, Table 7). TN and TP are the nutrient parameters collected in the ambient watershed monitoring network. The TN of 1.147 mg/l was 15 percent above the USGS (1999) background TN value of 1.0 mg/l. The average TP of 0.113 mg/l was 13 percent above the USGS (1999) background TP value of 0.1 mg/l. There are no permitted dischargers in the Canal Swamp and tributaries watershed. There is a small amount of agricultural land use in the Canal Swamp watershed, most of which is located along Rt. 624, east of Canal Swamp. Canal Swamp rises in the Westmoreland State Park where there is mostly forested land. The urban land use exists sparsely only along the roadways, totaling approximately 42 homes, and in Westmoreland State Park 12 cabins and some tent camping sites with one or two bathrooms. However, only approximately 3 of the homes are within one mile upstream of the station. Also on one sample date, September 27, 2010, abnormally high TN of 2.9 mg/L and TP of 0.43 mg/L were sampled. This almost always occurs during very high storm runoff, however flow was noted to be low on this date. While these concentrations were elevated, the low flow means that the nutrient load to the watershed on this date was also low. There appears to be slight anthropogenic impact upon the sampling station, therefore this TN and TP in Canal Swamp were considered to be of primarily natural origin

and not sufficient reason to preclude natural Class VII designation, especially given the low nutrient levels in the Popes Creek watershed upstream of the original listing station.

**Table 6. Instream Nutrients of Popes Creek Station 1APOP003.92.**

Parameter	Average Conc.	Number
<b>Total Phosphorus</b>	<b>0.047 mg/l</b>	(n=35)
Orthophosphorus	0.017 mg/l	(n=12)
Total Kjeldahl Nitrogen	0.525 mg/l	(n=12)
Ammonia as N	0.044 mg/l	(n=23)
<b>Nitrate as N</b>	<b>0.159 mg/l</b>	(n=12)
Nitrite as N	0.004 mg/l	(n=12)
<b>TN (TKN + NO<sub>3</sub> + NO<sub>2</sub>)</b>	<b>0.779 mg/l</b>	(n=35)
Nitrite + Nitrate, Total as N	0.213 mg/l	(n=23)

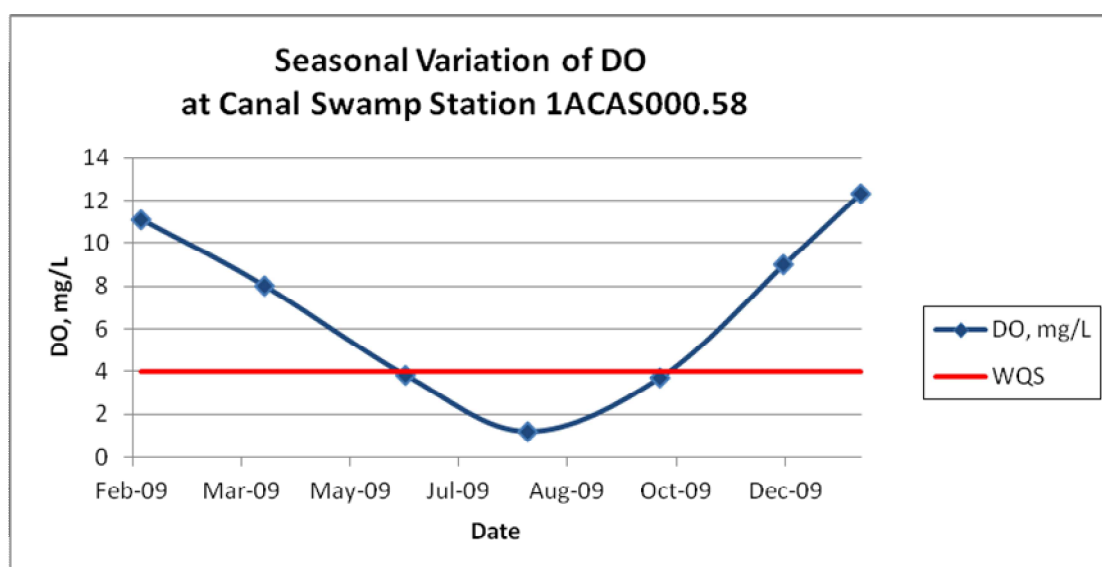
**Table 7. Instream Nutrients of Canal Swamp Station 1ACAS000.58.**

Parameter	Average Conc.	Number
<b>Total Phosphorus</b>	<b>0.113 mg/l</b>	(n=12)
<b>TN (TKN + NO<sub>3</sub> + NO<sub>2</sub>)</b>	<b>1.147 mg/l</b>	(n=12)

#### 5.4 Natural Seasonal DO Fluctuation

The 2011 DO data collected at the Canal Swamp station 1ACAS000.58 were graphed to demonstrate the natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high. This is depicted in Figure 14.

**Figure 16. Seasonal DO Variation at Canal Swamp at Rt. 624, February 2009 to January 2010.**



#### 5.5 Impact from Point Source Dischargers and Land Use

There are no active permitted point source dischargers in the Popes Creek and tributaries watershed.

The watershed is approximately 11206 acres (17.51 mi<sup>2</sup>) in size and is predominately forest (57 percent). Agriculture (hay/pasture 4.7 percent and cropland 13.5 percent) comprises 18 percent of the watershed. Urban areas compose approximately 4 percent of the land base. Wetlands comprise 9 percent of the watershed. The remaining 11.5 percent of the watershed is comprised of 7.4 percent other grasses and 4.1 percent open water. Per most recent aerial photography there are 128 homes in the non-tidal Popes Creek watershed and 42 homes in the Canal Swamp watershed. This equates to approximately one human habitation structure per 66 acres. Only 19 homes are within one mile upstream of the two sampling stations and 161 are farther than one mile away and approximately half of those are on Rt. 640 the greatest distance from the Popes Creek sampling station. Land use was not considered to have significantly impacted the swampwater conditions of Popes Creek and tributaries.

## 6. CONCLUSION

***The following decision process is proposed for determining whether low DO values are due to natural conditions:***

If slope is low (<0.50) AND

If wetlands or large areas of forested land are present along stream reach AND

If no point sources or point sources with minimal impact on DO AND

If nutrients are < typical background

❖ average (= assessment period mean) nitrate less than 0.6 mg/L

❖ average total nitrogen (TN) less than 1.0 mg/L, and

❖ average total phosphorus (TP) are equal to or less than 0.1 mg/L AND

If nearby streams without wetlands meet DO criteria,

THEN determine as impaired due to natural condition

→ assess as category 4C in next assessment

→ initiate WQS reclassification to Class VII Swamp Water

→ get credit under consent decree

There was one date with DO and pH data collected at 1APOP003.92, on 9/26/2002, when flows were estimated to be less than 7Q10 from the drainage area comparison with Piscataway Creek. The DO that day was 2.57 mg/L and pH was 6.27 S.U. These two data points were removed from the dataset and percent violations recalculated to be 8.3% violations for DO and 42% violations for pH at the listing station 1APOP003.92. DEQ does not recommend de-listing Popes Creek for low DO based on the reduction in DO percent violations from 10.8 to 8.3 percent, because both Fox Hall and Canal Swamps still have 15 and 38 percent DO violations, respectively.

The percent slope of Popes Creek and tributaries ranged from 0.25% to 0.34% slope (Table 5). These were below the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swampy areas and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

Visual inspection of Popes Creek and tributaries revealed swampy areas and heavy tree canopy in large swamp segments. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs.

The VADEQ collected nutrient data from the original listing station 1APOP003.92 (July 2003 to December 2012, Table 6). The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

The VADEQ collected nutrient data from the ambient watershed network station 1ACAS000.58 on Canal Swamp, a tributary of tidal Popes Creek (Feb 2009 to Nov 2010, Table 7). TN and TP are the nutrient parameters collected in the ambient watershed monitoring network. The TN of 1.147 mg/l was 15 percent above the USGS (1999) background TN value of 1.0 mg/l. The average TP of 0.113 mg/l was 13 percent above the USGS (1999) background TP value of 0.1 mg/l. There are no permitted dischargers in the Canal Swamp and tributaries watershed. There is a small amount of agricultural land use in the Canal Swamp watershed, most of which is located along Rt. 624, east of Canal Swamp. Canal Swamp rises in the Westmoreland State Park where there is mostly forested land. The urban land use exists sparsely only along the roadways, totaling approximately 42 homes, and in Westmoreland State Park 12 cabins and some tent camping sites with one or two bathrooms. However, only approximately 3 of the homes are within one mile upstream of the station. Also on one sample date, September 27, 2010, abnormally high TN of 2.9 mg/L and TP of 0.43 mg/L were sampled. This almost always occurs during very high storm runoff, however flow was noted to be low on this date. While these concentrations were elevated, the low flow means that the nutrient load to the watershed on this date was also low. There appears to be slight anthropogenic impact upon the sampling station, therefore this TN and TP in Canal Swamp were considered to be of primarily natural origin and not sufficient reason to preclude natural Class VII designation, especially given the low nutrient levels in the Popes Creek watershed upstream of the original listing station.

Popes Creek and tributaries exhibit natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Popes Creek and tributaries watershed.

The watershed is approximately 11206 acres (17.51 mi<sup>2</sup>) in size and is predominately forest (57 percent). Agriculture (hay/pasture 4.7 percent and cropland 13.5 percent) comprises 18 percent of the watershed. Urban areas compose approximately 4 percent of the land base. Wetlands comprise 9 percent of the watershed. The remaining 11.5 percent of the watershed is comprised of 7.4 percent other grasses and 4.1 percent open water. Per most recent aerial photography there are 128 homes in the non-tidal Popes Creek watershed and 42 homes in the Canal Swamp watershed. This equates to approximately one human habitation structure per 66 acres. Only 19 homes are within one mile upstream of the two sampling stations and 161 are farther than one mile away and approximately half of those are on Rt. 640 the greatest distance from the Popes Creek sampling station. Land use was not considered to have significantly impacted the swampwater conditions of Popes Creek and tributaries.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for Popes Creek and tributaries located in waterbody identification codes (WBID) VAP-A31R. This obviates the need for a future DO and pH TMDL for the watershed.

DEQ performed the assessment of the Popes Creek and tributaries low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

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